FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	
15336	
U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	
10/069846	
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE
PCT/AUOO/01038	1 September 2000 (01.09.99)
PRIORITY DATE CLAIMED	
2 September 1999 (02-09-99)	

TITLE OF INVENTION

IMPROVED SOUND PROCESSOR FOR COCHLEAR IMPLANTS

APPLICANT(S) FOR DO/EO/US

Graeme Milbourne Clark

David Bruce Grayden

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Courtsey copy of Inernational Application
Assignee: The Bionic Ear Institute

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
10/069846	PCT/AUOO/01038	15336

24. The following fees are submitted:.		CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :			
☒ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1040.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$1,040.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	16 - 20 =	0	x $18.00	**$0.00**	
Independent claims	2 - 3 =	0	x $84.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☒	**$280.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,450.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$0.00**	
SUBTOTAL =				**$1,450.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).			+	**$0.00**	
TOTAL NATIONAL FEE =				**$1,450.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$1,450.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$1,450.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **19-1013 SSMP** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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February 28, 2002
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IMPROVED SOUND PROCESSOR FOR COCHLEAR IMPLANTS

Field of the Invention

This invention relates to improvements in sound processors for cochlear implants, and more particularly to a Differential Rate Sound Processor (DRSP)

Background of the Invention

The multi-channel cochlear implant was first implanted in 1978. Early signal processing designs extracted the second formant (F2) and pitch (F0) to control electrode stimulation. The frequency of F2 controlled the location of electrode stimulation, and F0 controlled the rate of stimulation. This was later improved by also extracting the first formant (F1) and adding a second stimulated electrode for each pitch period. The MULTI-PEAK (MPEAK) stimulation strategy added stimulation of a number of fixed electrodes to better represent high-frequency information. The next stages of development were the SMSP and SPEAK strategies. These were a departure from the others at they used a fixed stimulation rate and stimulated electrodes that corresponded to maxima in the sound spectra. Another fixed-rate strategy, CIS, was developed overseas. This strategy stimulated all of a small number of electrodes to represent the sound spectra. All of the above processing strategies involve fixed-rate sound processing.

The named inventors have determined that some speech features are better perceived using low-rates of simulation, while some are better perceived using high rates of stimulation. Higher rates of stimulation present more information about phonetic manner of articulation, but spectral information tends to be smeared at such higher rates.

Summary of the Invention and Object

It is an object of the present invention to provide an improved sound processor for use with cochlear implants in which the problems associated with fixed rate stimulation are ameliorated.

The invention provides in one form an improved sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant for stimulation of the auditory nerve, said sound processing means including means for generating electrical signals to be applied to the electrodes having different predetermined rates of stimulation.

In this first form of the invention, the cochlear implant preferably has basal electrodes and apical electrodes and the means for generating electrical signals to be applied to the apical electrodes have a different rate of stimulation, the electrical signals to be applied to the basal electrodes having a higher rate of stimulation than the electrical signals to be applied to the apical electrodes.

By causing stimulation of the basal electrodes at a higher rate of stimulation than the apical electrodes, the manner of articulation features of speech will be more optimally presented to the cochlear implant user, leading to improved speech understanding performance. High rates of stimulation at the basal electrodes will present good information about temporal events and frication. The low rates of stimulation of the apical electrodes will present good spectral information in this regard, where most place of articulation features reside.

In a preferred embodiment, the more apical electrodes will be chosen as those that contain the voice bar and lower formants of speech. In this frequency region, spectral detail is important and the apical electrodes will be stimulating using a stimulation rate of between about 250 cycles per second and about 800 cycles per second, depending on the user. By adopting stimulation rates falling within the above range, better information about place of articulation of speech, which is largely represented by the formant structure, is obtained by the user.

The more basal electrodes represent higher frequency components of the incoming sound, and higher rates of stimulation of these electrodes will be used

to better represent noise and more precisely present information about temporal events such as rapid changes in amplitude. The latter is important for perception of manner of articulation and voicing. These electrodes will be stimulated at a higher rate than the apical electrodes, with stimulation rates at or above about 800 cycles per second, and preferably up to about 1600 cycles per second, being selected depending on the user.

In the case of an implant having 20 electrodes available for stimulation, the apical electrodes are electrodes 0 to 12, and the basal electrodes are electrodes 13 to 19. The apical electrodes represent sound frequencies from 0 to about 2700Hz, while the basal electrodes represent frequencies from about 2700Hz to about 7900Hz. The stated apical electrode frequencies are sufficient to contain the first three formants of most speech.

In a particularly preferred form of the invention, the apical electrodes are stimulated at about 250 cycles per second while the basal electrodes are stimulated at about 1500 cycles per second. To ensure that stimulation levels are suitable for these different rates, the threshold (T) levels and comfort (C) levels of the patient are carefully set. The electrodes to be stimulated are chosen by selecting the eight largest spectral energies within filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT) which is performed by the processor.

In another form, the invention provides an improved sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting to electrical stimulation signals for application to the electrodes of the cochlear implant whereby the auditory nerve is electrically stimulated, said sound processing means having means for varying the rate of stimulation of the electrical stimulation signals depending on the parameters of the sound received by the sound receiving means.

By varying the rate of stimulation of the cochlear implant electrodes depending on the incoming speech signal, key speech features will be more optimally presented to the cochlear implant user thereby leading to improved speech understanding performance.

In a preferred form of this aspect of the invention, the sound processing means will be programmed to continually adjust the rate of stimulation of the electrical stimulation signals depending on the parameters of the incoming speech signal. To this end, the incoming speech signal will be processed to detect events that are better represented using a higher rate of stimulation. Such events include plosive onset bursts, frication and other rapid spectral changes. The rate of stimulation across all electrodes will be increased for the average duration of these events. The standard rate will be between 250 cycles/s and 800 cycles/s depending on the user. The higher rate will be above about 800 cycles/s, and preferably up to about 1600 cycles/s, also depending on the user.

In order that the invention may be more readily understood, one presently preferred embodiment of the invention will now be described.

Description of Preferred Embodiment

The invention is preferably designed for use with the CI-24M Cochlear Implant as manufactured by Cochlear Ltd, and as described in US Patent No. 4532930, the contents of which are incorporated herein by cross-reference, and later patents by Cochlear Ltd to be found in the patent literature.

Although the CI-24M Implant will be used in most cases, the invention could be applied to any implant that uses pulsatile stimulation. The stimulation strategy is based on the Spectral Maxima Sound Processor (SMSP), which is described in United States Patent 5597380 and Australian Patent 657959, the contents of which are incorporated herein by cross reference although other strategies may be used with similar results. For example, the SPEAK strategy as discussed in US Patent No. 5,597,380, the contents of which are incorporated by cross reference.

The electrode selection strategy from the SMSP is varied to ensure that electrodes are stimulated at the desired predetermined frequencies for each cycle of stimulation. The preferred signal processing device will be the SPEAR processor, which is currently under development at The Bionic Ear Institute, and which is described in the following paper :

Zakis, J.A. and McDermott, H.J. (1999). "A new digital sound processor for hearing research," Proceedings of the Inaugural Conference of the Victorian Conference of the Victorian Chapter of the IEEE Engineering in Medicine and Biology Society, February 22-23, pp. 54-57. The contents of this paper are similarly incorporated herein by cross reference.

The processor is a generic processor based on the Motorola DSP56300 family, such as the DSP56302, or the DSP56309, although any digital signal processor, including those produced by Cochlear Ltd and their competitors, could be used to run the differential rate sound processor program of the present invention, provided they have adequate processing speed.

In the implementation of the first form of the invention, the differential rate stimulation processor software embodying the invention is downloaded to the SPEAR processor and stored on EPROM. Patient map details, including frequency bands, threshold (T) levels and comfort (C) levels, are also stored on the device. Monopolar stimulation mode is used to reduce current levels and for longer battery life.

For the case where 20 electrodes are available for stimulation, the apical electrodes are electrodes 0 to 12, and the basal electrodes are electrodes 13 to 19. The apical electrodes then represent frequencies from 0 to 2700Hz; the basal electrodes represent frequencies from 2700Hz to 7900Hz. The stated apical electrode frequencies are sufficient to contain the first three formants of most speakers' speech.

The apical electrodes are stimulated at about 250 cycles/s and the basal electrodes at about 1500 cycles/s. The patient's T and C levels are carefully set

to ensure that stimulation levels are suitable for the two different rates and adjustments made if necessary. The electrodes to be stimulated are chosen by selecting the eight largest spectral energies within filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT).

The values quoted above are examples. Patient-to-patient variability is large and some need higher stimulation rates on the apical electrodes and/or lower stimulation rates on the basal electrodes. These are determined for each individual by evaluating a number of rate combinations in every day usage. Also, some patients do not have as many electrodes available and so the choice of electrodes is altered to suit their situation. However, the spectral ranges of the apical and basal electrodes remain much the same.

By using the Differential Rate Sound Processor (DRSP) program of the invention, features of speech will be more optimally presented to the cochlear implant user leading to improved speech understanding performance.

In the implementation of the second aspect of the invention, the software necessary to provide a variable rate of stimulation depending on the incoming speech signal is downloaded to the SPEAR processor and stored on an EPROM. Patient map details, including frequency bands, threshold (T) levels and comfort (C) levels, are also stored on the device. Monopolar stimulation mode is used to reduce current levels and for longer battery life.

The standard rate of stimulation is about 250 cycles/s and the higher rate is about 1500 cycles/s. The patient's T and C levels are carefully set to ensure that stimulation levels are suitable for the two different rates. The electrodes to be stimulated are chosen by selecting the eight largest spectral energies within filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT).

The changes in spectral energies and the amount of frequency energy are monitored over time. When there is a significantly large change between frames separated by the period of the lower stimulation rate then the higher stimulation

rate is used for 50 ms. This procedure locates plosive bursts and other rapid spectral changes. The higher stimulation rate is also used when the ratio of energy below about 300Hz to that above about 2000Hz is less than about 0.5. This locates phonemes with significant frication.

The values quoted above are examples. Patient-to-patient variability is large and some need a higher stimulation rate for the standard rate and/or a lower stimulation rate for the higher rate. These are determined for each individual by evaluating a number of rate combinations in every day usage. Thresholds for changes in energy and ratio of energies are also adjustable for each individual.

CLAIMS:

1. A sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant for stimulation of the auditory nerve, said sound processing means including means for generating electrical signals to be applied to the basal electrodes having different predetermined rates of stimulation.

2. The sound processor of claim 1, wherein the cochlear implant has one form of the invention, the cochlear implant has basal electrodes and apical electrodes and the means for generating electrical signals to be applied to the apical electrodes have a different rate of stimulation, the electrical signals to be applied to the basal electrodes having a higher rate of stimulation than the electrical signals to be applied to the apical electrodes.

3. The sound processor of claim 2, wherein the more apical electrodes are selected for stimulator signals that represents the voice bar and lower formants of the sounds.

4. The sound processor of claim 3, where the more apical electrodes apply stimulation signals having a stimulation rate of between about 250 cycles per second and about 800 cycles per second depending on the user, to provide precise spectral and place of articulation information.

5. The sound processor of any one of claims 2 to 4, wherein the more basal electrodes apply stimulation signals having a stimulation rate of at or above

about 800 cycles per second depending on the user, to provide precise information about temporal events and frication.

6. The sound processor of any one of claims 2 to 5, including a twenty (20) electrode implant, the apical electrodes are electrodes 0 to 12 and the basal electrodes are electrodes 13 to 19, the apical electrodes representing sound frequencies from 0 to about 2700Hz, while the basal electrodes represent frequencies from about 2700Hz to about 7900Hz, the apical electrode frequencies, are sufficient to contain the first three formants of most speakers speech.

7. The sound processor of any one of claims 2 to 6, wherein the apical electrodes are stimulated at about 250 cycles per second while the basal electrodes are stimulated at about 1500 cycles per second.

8. The sound processor of claim 7 wherein the threshold (T) levels and comfort (C) levels of the patient are carefully set, the electrodes to be stimulated are chosen by selecting the eight largest spectral energies within filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT) which is performed by the processor.

9. A sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting to electrical stimulation signals for application to the electrodes of the cochlear implant whereby the auditory nerve is electrically stimulated, said sound processing means having means for varying the overall rate of stimulation of the electrical stimulation signals depending on the parameters of the sound received by the sound receiving means.

10. The sound processor of claim 9, wherein the sound processing means is programmed to continually adjust the rate of stimulation of the electrical stimulation signals depending on the parameters of the incoming speech signal, to this end, the incoming speech signal will be processed to detect events that are better represented using a higher rate of stimulation.

11. The sound processor of claim 9 or 10, as defined in any one of claims 2 to 8.

12. The sound processor of any preceding claim, wherein the implant is one which uses pulsatile stimulation.

13. The sound processor of any preceding claim wherein a SPEAR processing device is programmed using the Differential Rate Sound Processor (DRSP) program defined in any preceding claim to optimally present the features of speech to the implant.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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Published:
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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(54) Title: IMPROVED SOUND PROCESSOR FOR COCHLEAR IMPLANTS

(57) Abstract: An improved sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant for stimulation of the auditory nerve, said sound processing means including means for generating electrical signals to be applied to the basal electrodes having different predetermined rates of stimulation and the implant having basal electrodes and apical electrodes and the means for generating electrical signals to be applied to the apical electrodes have a different rate of stimulation, the electrical signals to be applied to the basal electrodes having a higher rate of stimulation than the electrical signals to be applied to the apical electrodes.

Docket No.
15336

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

IMPROVED SOUND PROCESSOR FOR COCHLEAR IMPLANTS

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 1 September 2000 as United States Application No. or PCT International Application Number PCT/AU00/01038

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
PQ2612	Australia	02/09/1999	☐
(Number)	(Country)	(Day/Month/Year Filed)	
			☐
(Number)	(Country)	(Day/Month/Year Filed)	
			☐
(Number)	(Country)	(Day/Month/Year Filed)	

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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